British Heart Journal, 1970, 32, 771–773.

Life units
A discussion in the Department of Cardiology, Royal Perth Hospital, Australia

O. B. Tofler[1]

Q. I have heard of your life unit system. What is it all about?

A. It was formulated in order to answer the question 'how much good are we doing by replacing heart valves?'

Q. Don't you think surgical results which break cases down into good and bad risks and which state mortality rate and grade results into good, improved, and no change are adequate? Don't you think presentation of surgical results in terms of percentage survivors at yearly intervals is sufficient?

A. Not really, because they avoid the big question in valve surgery today – when to advise operation? The life unit system which focuses on this problem, enables us to make a retrospective evaluation of a decision to operate at a certain point in a patient's life. It also takes into account the type of cases offered for surgery, and enhances the value of a successful operation in poor risk cases. It requires an informed guess to be made of the number of years remaining to any particular patient and the quality of life he or she can be expected to lead if an operation is not performed. At yearly intervals after operation, assessment is made of the benefits derived in terms of years of life and quality of life. Comparisons of the expected and observed life units enable us to answer the question how much good we are doing. The best centres need to ask this question from time to time. The others should be asking it all the time. It is comforting that as the years go by the 'good' tends to become more obvious despite unexpected setbacks.

Q. What are life units?

A. The product of the quality of life to which an arbitrary figure has been given –

e.g. Life without restriction	5
Can work well, but slight restriction	4
Part-time work, moderate restriction	3
No work, but not bed-ridden	2
Life virtually confined to bed	1

and the number of years throughout which this life is led –

e.g. 4 (quality) × 3 (years) = 12 (life units).

Q. How can you equate life itself with quality of life? They are two different concepts, two different qualities. Some people value life so greatly they don't care how ill they are. Others can't bear to live unless they are active.

A. I am not equating them. I am multiplying them to obtain a useful measure called a life unit. It is a new term and people react to new things. I can justify it to some extent by saying that two aspects of life, duration on the one hand and social usefulness, 'quality', and physical ability on the other are being intimately associated. I agree that people place different values on duration of life and quality of life. Efforts at prolonging life should, in my opinion, take into account the resulting social usefulness of the individual. This is done by the life unit approach to retrospective evaluation of our efforts.

Q. I don't agree with your approach to the assessment of quality of life. You are making it in terms of what a person can do, which I agree is objective; but it can be made in terms of social usefulness, both to society and to the patient's own family, which is semi-objective. I also suggest that a subjective assessment of the quality of life which takes into account the patient's enjoyment of life cannot be made. Don't you think we are dealing with a very contentious moral issue?

A. Yes, I do. I agree with what you have said about the quality of life. All these factors will influence the decision relating to the time to operate. In any retrospective evalu-

Received 20 April 1970.

[1] Department of Cardiology, Royal Perth Hospital, Box X. 2213, G.P.O., Perth, Western Australia 6001.

ation of that decision I can only take into account the subject's ability to do things.

Q. Can you give me some examples of how you apply this system?

A. Certainly. A woman of 62 with aortic stenosis and mitral incompetence on full medical treatment and having recurrent attacks of pulmonary oedema despite virtual complete bed-rest has no life units left –

$$\text{Expected life units} = 0 \times 1 = 0.$$

Four years after operation she can do her own housework and cooking, though is limited in exercise tolerance –

$$\text{Observed life units} = 4 \times 3 = 12.$$

The triumph of operation in this case is clearly stated. Had she died no life units would have been lost. Another example – a little more complicated. One could calculate (on the basis of careful history, physical examination, and detailed investigation plus response to treatment) that a man of 50 with aortic incompetence had approximately two years to live. During this time you could expect him to lead a quiet life at home, able to drive a car but not able to work. In life units this could be written –

$$\text{Expected life units} = 2 \times 2 = 4.$$

Let us assume that the aortic valve is replaced and that he develops a hemiplegia with mental changes and is a burden to his wife four years after operation. Haemodynamically he is improved, but in terms of his ability to mix in society he is worse. He might even be classified in the improved group by an enthusiastic surgeon. He is counted as a success when it comes to estimating surgical mortality which is what everyone takes notice of. The result expressed in life units –

$$\text{Observed life units} = 4 \times 1 = 4$$

gives a more sombre view of the sequence of events.

Q. Does thinking in terms of your life units influence the decision to recommend surgery?

A. Yes, it does along with other well-accepted factors such as operative risk, indications for and against operation, one's assessment of the patient's condition, the patient's wishes, and other subtle factors that defy definition.

Q. Let's come back to the validity of your system. You are comparing an expected or estimated value or guess with an observed value. Can you really do this?

A. Such is the lack of knowledge of cardiac function, this is the best we can do. As a matter of fact what we really do in our minds when we recommend an operation at a certain point in a patient's life is to compute that it will be to his or her advantage. We are frightened to say how we arrive at this decision because of the uncertainties involved. I suggest that the way we think logically about these problems is to do very much the same as I am doing when I work out life units. If we fully investigate any patient both clinically and haemodynamically we will be able to judge fairly accurately the number of years remaining for a particular patient and at what level of existence.

Q. You may be able to do this for patients with mitral valve disease but patients with aortic valve disease are very unpredictable. As you know they can die suddenly at any time.

A. I don't entirely agree with you. A physician who orders his patient's life can impose restrictions that minimize this possibility. For example, I don't accept such sweeping statements that patients with aortic stenosis have two years to live after they develop cardiac pain. Patients vary greatly, and it is up to those who understand patients to manipulate living conditions and tablets to the patient's advantage. The advantages of thinking in terms of units are that we are encouraged to study further in each patient factors that may lead to deterioration, to study the cardiac muscle function, and above all to know our patient extremely well. If two or three physicians sit down and discuss all the details of a patient they will nearly always be able to agree on the expected life units.

Q. What have you learnt so far from your thinking in terms of life units?

A. The good we do for 'mitrals' is much greater than we have achieved for 'aortics'. This is not the experience of other units. Also the good we do for multiple valve replacements, including emergencies, is better than for 'aortics'. Evaluation of results in the accepted fashion gives a much different impression. Even if we tally up results in terms of numbers of years and ignore the quality of life the impression gained is a different one.

In conclusion, I am putting the life unit system forward as another, admittedly imperfect,

approach to the retrospective evaluation of valve replacement surgery.

Note Because I am indebted to my colleagues for many of the ideas contained in these few pages, I decided to submit these thoughts in the question and answer format.

Addendum

One could use the theory of probability in evaluating uncertainty.

Suppose one gives the man of 50 with aortic incompetence a probability or a chance of 90 per cent to live 2 years, 8 per cent to live 3 years, 2 per cent to live 4 years.

His expected span of life, $E(x) = \sum_{x=0}^{\infty} x\, f(x)$

where $E(x)$ = number of years (random variable) and probability of living $\sum f(x) = 1$

Therefore $E(x) = 2(0.90) + 3(0.08) + 4(0.02) = 2.12$ years

The quality of life during this period might be during the 1st year from now 2, 2nd year 2, 3rd year 2, 4th year 1, which on the average:

$$\frac{1(2) + 1(2) + 1(2) + 1(1)}{4} = \frac{7}{4} = 1.75$$

Therefore

Life Units = (quality of life on the average) (1.75) × (expected number of years) (2.12) = 3.7 units

This is very close to the original conclusion of 4 life units.

It could be argued that the numbers place undue emphasis on the quality of life. This has been done deliberately to avoid the use of decimals.